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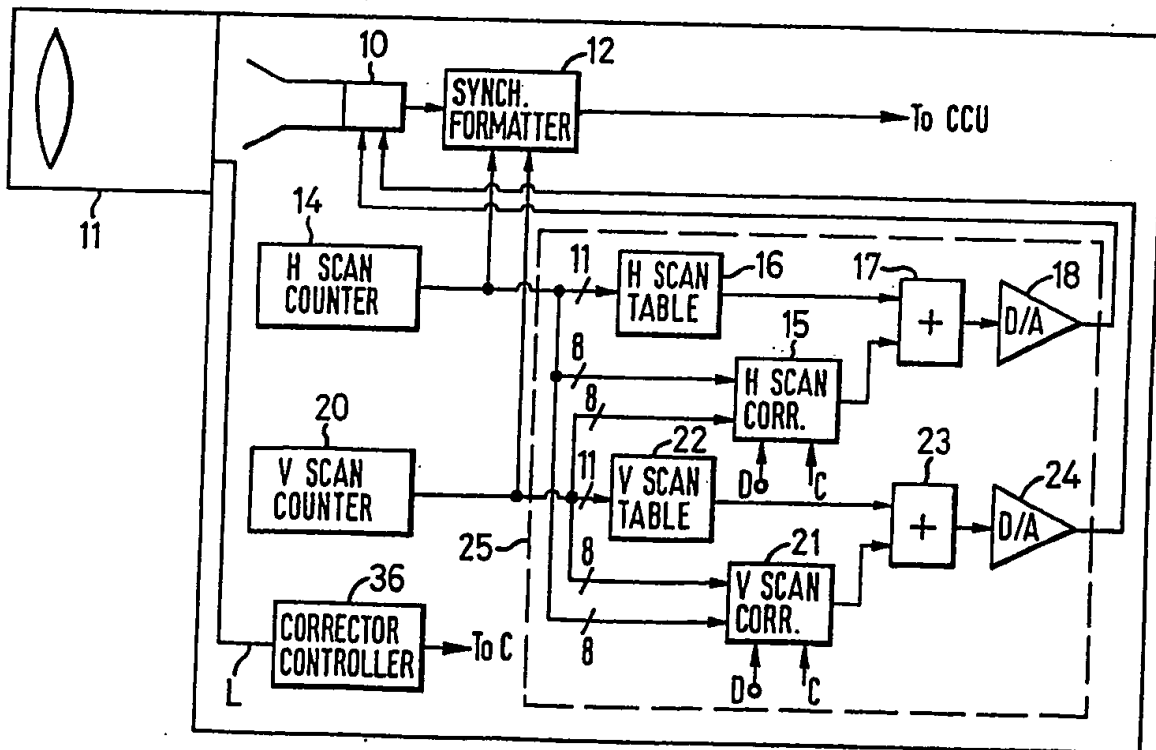
(56) Documents cited
GB 2146879 A GB 2074416 A GB 1353147 A

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(54) Video camera aberration correction

(57) A video camera includes a camera tube 10 and a tube target for sensing light via an optical system 11, scanning circuitry for causing scanning of the tube target 10 and producing output signals according to the light intensity sensed by the tube target 10. A scanning table store 16, 22 for producing digital deflection signals for a scanning pattern, and a scan corrector 25 for producing digital correction signals for modifying the scanning pattern to compensate for the effects of imperfections of the optical system 11 is provided. A tube camera producing high quality images can thereby be produced.

FIG. 2



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FIG. 1A

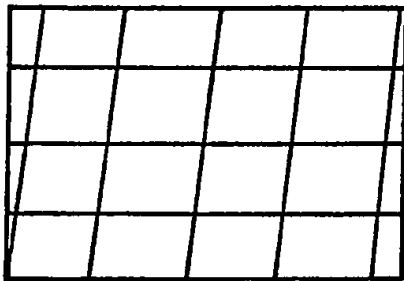
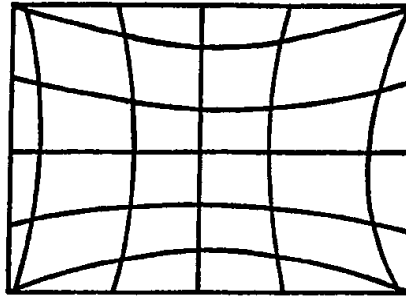


FIG. 1B

FIG. 1C

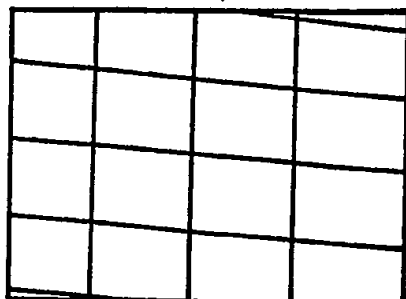
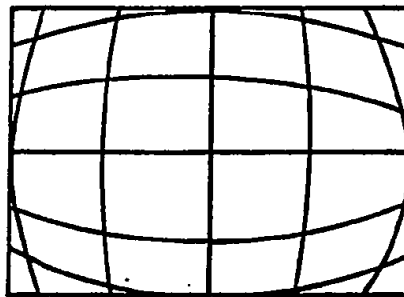
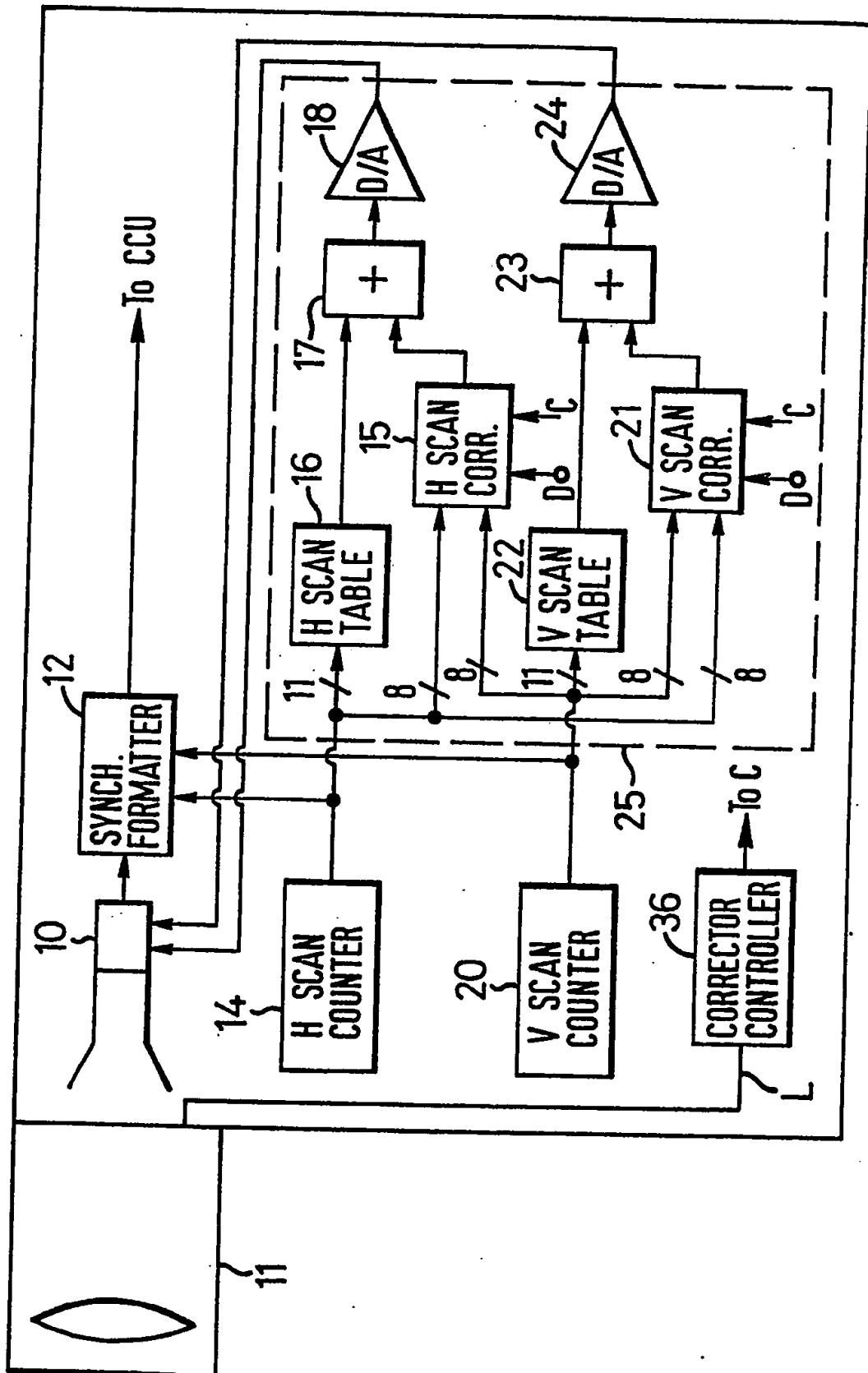


FIG. 1D

FIG. 2



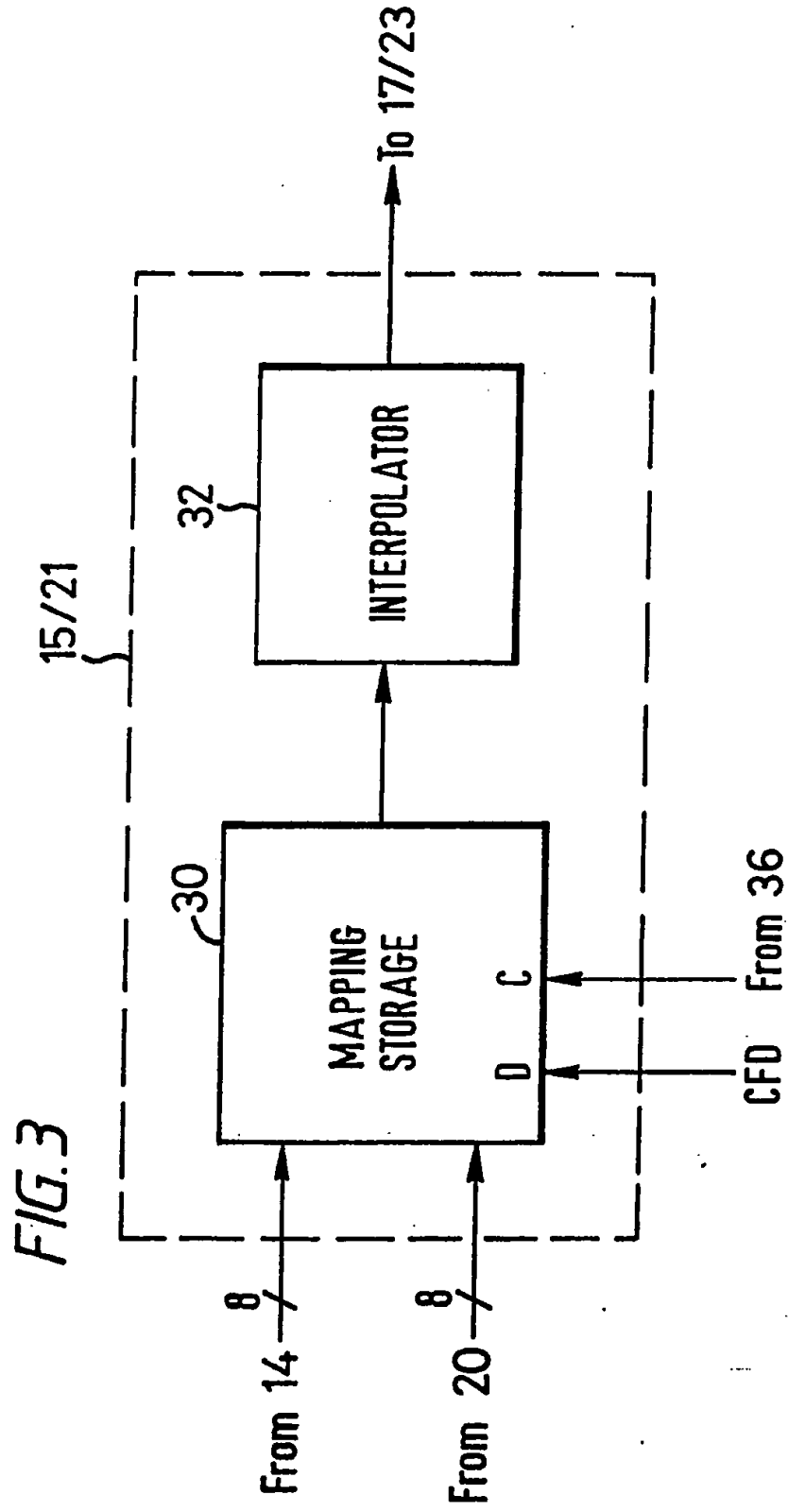
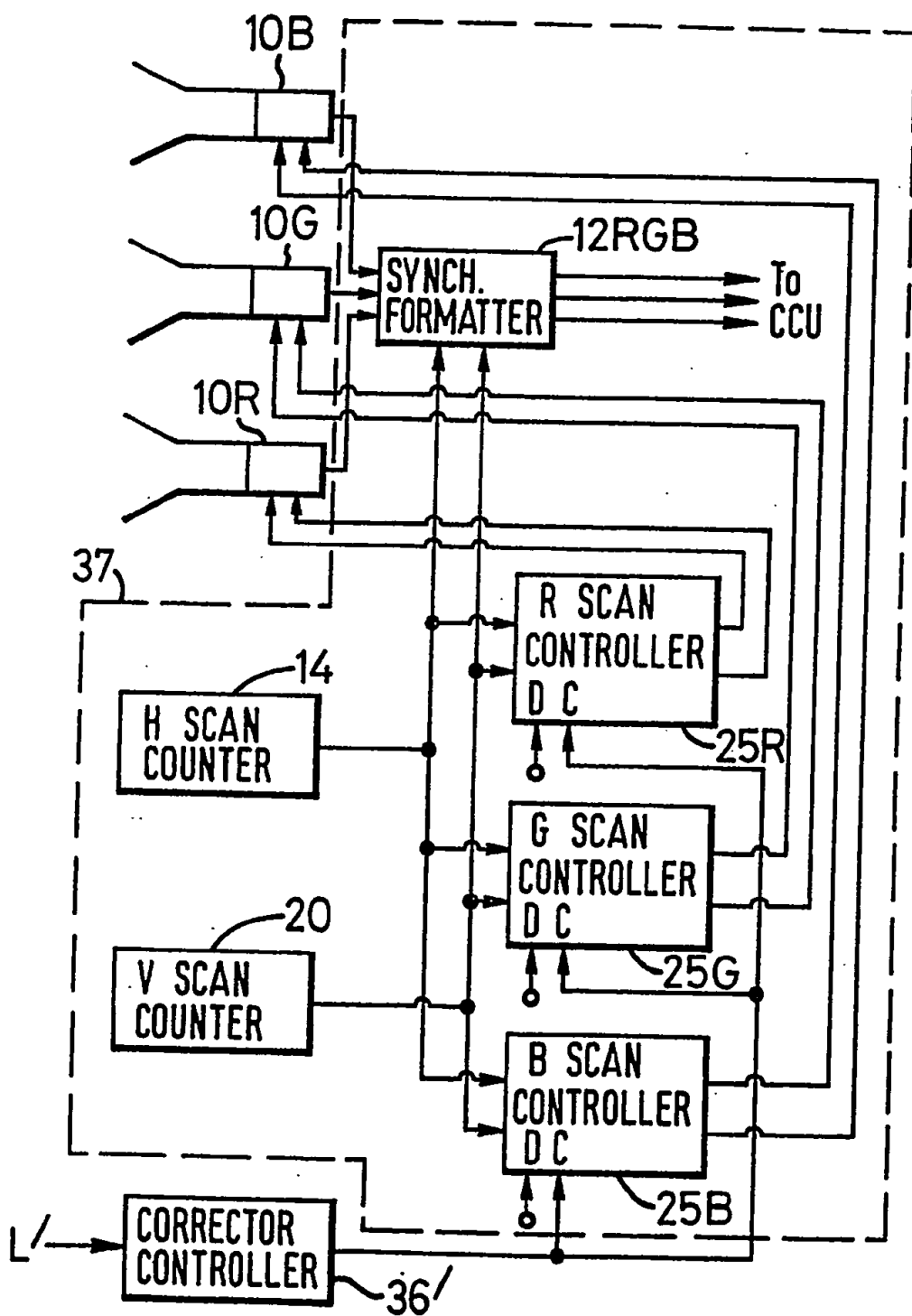


FIG. 4



VIDEO IMAGE CAPTURE APPARATUS

The invention relates to video image capture apparatus including means for compensating for the effects of optical imperfections.

5 A high definition television system, for example, with a resolution of 1920 pixels by 1035 active lines per frame, makes very high demands on image capture apparatus such as tube cameras. High accuracy is required in capture resolution and also in picture geometry and registration. The resolution limits tend primarily to be a
10 function of the tube of a tube camera whereas the accuracy of picture geometry and registration is primarily determined by the camera's optical system through which light has to travel before reaching the sensor arrangement.

Significant distortion of the picture geometry can be introduced
15 into a picture output from the camera even when high quality lenses are used. Modern television tube cameras are typically provided with zoom lenses which may work over a relatively large optical range and varying fields of view. Due to the different optical and mechanical arrangements of the optical system contained in a zoom lens, it is
20 usually only possible to provide a highly accurate geometric arrangement at one point in the centre of range of zoom operation of the lens. The better the lens, the less will be the distortion generated at other positions. However, it is not practically possible to make a zoom lens which is optically perfect at all points within the
25 optical range. Typically, the design of a lens includes compromises to avoid excessive distortion at any particular point over its range of zoom operation. Similarly, compromises have to be made to avoid excessive distortion over the focusing range of a lens, whether a zoom lens or otherwise.

30 Other distortion effects can occur due to the placement or adjustment of the image sensor or sensors within a camera, for example in a colour camera where an optical splitter is employed. These effects occur with fixed focal length lenses or zoom lens.

As well as geometric distortions which can be introduced in the
35 optical path through a lens or through the physical placement or adjustment of the image sensor, chromatic distortions may appear at the image sensor. This is because the optical elements in the lens affect

different light frequencies differently. Traditionally, a balance has to be met between the geometrical and registration errors which are considered unacceptable, and the expense of the lens. The tighter the specification of the lens (i.e. the lower the level of geometric, registration and chromatic errors which are acceptable), the more expensive it will be. It is to be noted that the cost of the lens in a camera system, for example a zoom lens on a video camera, is a significant portion of the total cost of the camera system, particularly where a very tight specification is required.

Figure 1 illustrates four well known examples of geometric distortions which can be introduced into a picture by an optical system.

Figure 1A illustrates the so called pin-cushion effect.

Figure 1B illustrates a skew effect.

Figure 1C illustrates barrel distortion.

Figure 1D illustrates a tilt effect.

The distortions which occur in a lens system can be characterised to a first approximation by combination of linear distortion (tilt and/or skew) and second order parabolic distortion (barrel or pin-cushion distortion). Tube cameras are known where electronic means are employed to approximate a correction to these distortions by applying inverse cancelling signals to the horizontal and vertical scan drives of the tube. In other words, rather than attempting, for instance, to arrange for the horizontal scans to be as near to linear as possible, correction signals are generated to modify the output of the horizontal and vertical scan drives to compensate for a distortion encountered. For example, with regards to Figure 1A, if pin-cushion distortion is caused by the optical system, then the horizontal and vertical scan drives of the tube can be controlled so that the electron beam traces a pattern to compensate for the distortion, so that signals can be output from the tube camera which would reflect the original image without the distortions introduced by the optical system. Such electronic means are widely used in current tube cameras. However, these cancelling signals are normally generated in analogue circuitry and cannot compensate for distortions which are not characterised by combinations of first and second order effects. An object of the invention, therefore, is to provide a more flexible way of generating

correction signals for compensating for the effects of optical imperfections in the optical system.

In accordance with the present invention, there is provided a video image capture apparatus comprising at least a tube having a tube
5 target for sensing light via an optical system, scanning circuitry for causing scanning of the or each tube target and producing output signals according to the intensity of the light sensed by the or each tube target, digital deflection signal generating means for producing digital deflection signals for a scanning pattern for the or each tube
10 target and, associated with the or each tube target, a scan corrector for producing digital correction signals for modifying the scanning pattern for the respective tube target to compensate for the effects of imperfections of the optical system.

Preferably, the or each scan corrector includes a horizontal scan
15 corrector for producing a digital horizontal correction signal, and a vertical scan corrector for producing a digital vertical correction signal. Advantageously, the digital deflection signal generating means produces a horizontal digital deflection signal and a vertical digital deflection signal, the or each horizontal scan corrector is associated
20 with a respective horizontal combining means and the or each vertical scan corrector is associated with a respective vertical combining means, the or each horizontal combining means combines the digital horizontal deflection signal with the digital horizontal correction signal from the associated horizontal scan corrector to produce a
25 digital horizontal scan signal and the or each vertical combining means combines the digital vertical deflection signal with the digital vertical correction signal from the associated vertical scan corrector to produce a digital vertical scan signal.

In this way many digital horizontal and vertical scan signals can
30 be produced for the scanning circuitry of the or each tube target. These scan signals have been corrected for the image distorting effects of imperfections of the optical system in a way that is independent of the form of the distortion. That is the distortion may be, for instance first order skew or tilt, second order barrel or pin-cushion,
35 or a higher order distortion or even a distortion that cannot be represented by an analytic function.

Preferably the digital scan signals are converted into analogue

scan signals so that the apparatus can control analogue scan circuitry.

Also preferably, the or each scanning pattern comprises a plurality of scan addresses, and the digital deflection signal generating means includes scanning counter means for sequentially
5 incrementing a horizontal and a vertical scan address for the or each scanning pattern. Such a scanning counter means provides an array of addresses for a two dimensional scanning pattern and facilitates the generation of deflection signals by the digital deflection signal generating means than can affect the scanning of the surface of the or
10 each tube target.

Further, the digital deflection signal generating means may comprise a horizontal scan table store associated with the or each tube target, the or each horizontal scan table store containing horizontal
15 deflection data and being responsive to the horizontal scan address from the scanning counter for producing the digital horizontal deflection signals and a vertical scan table store, associated with the or each tube target, the or each vertical scan table store containing vertical deflection data and being responsive to the vertical scan
20 address from the scanning counter for producing the digital vertical deflection signals.

Such a generating means is capable of generating scanning signals independently of any correction signals and so the or each tube target may be scanned even if the optical system and the or each tube and tube
25 target is unable to generate an information signal according to any varying parameters.

Preferably the or each horizontal scan corrector comprises a horizontal mapping table addressed by the horizontal and vertical scan addresses from the scan counter and interpolator means for
30 interpolating between data from the horizontal mapping table to produce the digital horizontal correction signal and the or each vertical scan corrector comprises a vertical mapping table addressed by the horizontal and vertical scan addresses from the scan counter and further interpolator means for interpolating between data from the
35 vertical mapping table to produce the digital vertical correction signal.

In this way, if correction function data of less than full pixel resolution is needed, for example, if the full pixel resolution of the

image capture apparatus is $n \times m$ pixels, correction function data at a resolution of $n/i \times m/j$ can be stored in the mapping tables. In a preferred embodiment of the invention $i = j = 8$.

Preferably, the or each scan corrector is responsive to control
5 signals, according to current parameters, to produce the correction signals for compensating for the effects of imperfections of the optical system. Advantageously, the control signals can be supplied by a corrector controller. The corrector controller senses, for instance,
10 the lens type, its current focusing position and, in the case of a zoom lens, its current focal length. These parameters may be constant or continuously varying. The corrector controller can supply the or each scan corrector with control signals according to the current parameters of the optical system and the or each tube, and tube target.

Such a video image capture apparatus can compensate for
15 distortion to an image created by the optical system in an efficient and effective way. The optical system may have varying parameters. For instance, the optical system may form part of a zoom lens. Even if the optical system is not part of a zoom lens, but a fixed focal length lens, it may be focused over a range of distances.

20 Advantageously apparatus according to the invention can form part of a colour camera. For instance three tube targets, each sensitive to light of a different primary colour, may sense light passing through the optical system. Distortions to an image at any of the targets, caused by imperfections of the optical system, can be separately
25 compensated for by separate digital correction signals. If desired, apparatus according to the invention could comprise any number of tube targets.

Preferably, if the apparatus comprises more than one tube target, but only a single optical lens system then an optical beam splitter
30 means is provided in the optical system before the tube targets. The beam splitter divides an image received by the optical system into a number of identical separate images, and passes each separate image to a respective tube target. In this way, a number of tube targets, each sensitive to light of different frequencies, can each receive the image
35 received by the optical system. The separate images sensed by each tube target may latter be combined. For instance, in the case of a colour camera comprising three tube targets that are each sensitive to

light of a different primary colour, the three primary colour images sensed by the targets may be combined to form a full colour image.

Optical distortions may also be introduced by the positioning of the beam splitter and by the beam splitter itself. Further, the position of the or each tube target may give rise to a distortion of an image and so this position could also be a varying parameter.

Examples of video image capture apparatus in accordance with the invention are described hereinafter with reference to the accompanying drawings in which:

Figure 1 illustrates typical types of distortion encountered in camera optics systems;

Figure 2 is a schematic block diagram of elements of a monochrome video image capture apparatus within a video camera;

Figure 3 is a schematic block diagram showing part of the apparatus of Figure 2 in more detail;

Figure 4 is a schematic block diagram of elements of a colour video image capture apparatus.

Figure 5 is a schematic illustration of an overview of a colour video image capture apparatus including the elements of Figure 4.

Figure 2 is a schematic block diagram of elements of a monochrome video camera. Only those elements which are necessary for an understanding of the present invention are illustrated in Figure 2. Other elements of the monochrome video camera can be conventional. Accordingly, therefore, the further elements of the video camera will not be described further herein with reference to Figure 2. As illustrated in Figure 2, the image capture apparatus includes an optical system 11 and a television camera tube 10. The optical system 11 comprises, for instance, a variable focus zoom lens of variable aperture. The camera tube 10 can be a conventional tube comprising a tube target and scanning circuitry for scanning the target to determine the illuminance information captured thereby. The illuminance signals output by the tube 10 are supplied to a synchronisation formatter 12 for producing video signals including synchronisation information which is supplied for further processing to a camera control unit (CCU) - not shown.

For controlling the scanning of the tube target, the camera comprises a horizontal scan counter 14 and an vertical scan counter 20.

In one example of a high definition television system, the horizontal scan counter 14 is an eleven bit counter arranged to cycle between 0 and 2199. The horizontal scan counter 14 can thus increment its count for each of 1920 active pixel positions along a scan line. The vertical scan counter 20 is also an eleven bit counter, however it is arranged to cycle between 0 and 1124. The vertical scan counter 20 is thus arranged to increment its count for each of 1035 active scan lines of the high definition television system.

The horizontal scan counter 14 output is used to access a horizontal scan table 16 which contains a standard deflection pattern, including line synchronisation flyback time for a line scan of the tube target. The output of the vertical scan counter 20 is used to access a vertical scan table 22 which contains the basic vertical deflection pattern, including vertical flyback, for scanning the tube target. The output of the horizontal scan table 16 is supplied to an adder 17 which connects to a digital to analogue convertor 18 for deriving analogue signals for driving the horizontal deflection circuitry of the tube 10. The output of the vertical scan table 22 is supplied to an adder 23 which in turn connects to a digital to analogue convertor 24 for deriving analogue control signals for controlling the vertical deflection circuitry of the tube 10. The arrangement of components thus far described would be sufficient for providing a standard scanning pattern over the tube target of the camera tube 10. However, assuming the data in the horizontal and vertical scan tables 16 and 22 are constant it would not be possible, for instance, to compensate for the effects of imperfections in the optical system 11 of the camera.

Accordingly, in addition to the components thus far described, the camera includes a horizontal scan corrector 15 and a vertical scan corrector 21, each preferably in the form of a read only memory (ROM). Both the horizontal scan corrector 15 and the vertical scan corrector 21 are connected to receive at least part of both the horizontal and vertical scan counts output by the horizontal scan counter 14 and the vertical scan counter 20. The output of the horizontal scan corrector 15 is applied to the adder 17 for modifying the output of the horizontal scan table 16. The output of the vertical scan corrector 21 is applied to the adder 23 for modifying the output of the vertical scan table 22. Each of the horizontal scan corrector 15 and the

vertical scan corrector 21 receive control information from a corrector controller 36 via a control input C. The control information reflects the current arrangement of varying parameters of the optical system 11 (e.g. the current focal length of the zoom lens, the focus setting the
 5 current aperture, etc.). The corrector controller 36 is connected to the optical system 11 of the camera tube 10 and is responsive to signals L from the optical system 11 according to the varying parameters to cause the control information to be supplied to the horizontal and vertical scan correctors 15 and 21 via the input C.
 10 Each of the horizontal scan corrector 15 and the vertical scan corrector 21 is also connected via a data connection D to an external connector (not shown) to receive correction function data (CFD) as will be explained with reference to Figure 3.

Figure 3 is a schematic block diagram illustrating the form of
 15 both the horizontal scan corrector 15 and the vertical scan corrector 21. Both scan correctors 15 and 21 comprise mapping storage 30 in the form of a look-up table, or random access memory and an interpolator 32. The mapping storage uses horizontal and vertical address data from the horizontal scan counter 14 and from the vertical scan counter 20,
 20 in combination with the control information via the control input C to select correction function data for output. The correction function data are representative of a necessary adjustment to the scanning of the tube target in the camera tube 10. As illustrated, the mapping storage 30 receives eight higher order bits from each of the horizontal
 25 scan counter 14 and the vertical scan counter 20. In this way, the top eight bits of the horizontal and vertical addresses can be used to define a grid of 256×256 points (which corresponds to a grid at an 8×8 pixel resolution). Correction function data are stored in the mapping storage 30 for the locations at the intersections of the grid.
 30 The interpolator 32 is provided for interpolating between the grid locations in order to form corrective signals at a pixel accuracy for the adder 17 in the case of the horizontal scan corrector 15, and to the adder 23 in the case of the vertical scan corrector 21.

The correction function data (CFD) defining the mapping functions
 35 are downloaded into the mapping storage 30 via data connection D from an external source at an initialisation time. These data are specific to a particular lens and define the correction function data to be

output for each combination of horizontal and vertical scan counts (from the scan counters 14/20) and control information (from the corrector controller 36).

Figure 4 is a schematic block diagram showing elements of a colour camera in accordance with the invention. Only those elements which are essential to an understanding of the invention are described. Other features which are not essential can be conventional. The colour camera comprises three television camera tubes (e.g. saticon tubes) namely a blue tube 10B, a green tube 10G, and a read tube 10R. As is shown more clearly in Figure 5, the camera tubes each receive images to be captured via an optical system 11' including a beam splitter 13. The beam splitter 13 forms three separate images from a single image entering it from the lens of the optical system 11'. Each image is passed to a different one of the camera tubes 10B, 10G and 10R. From the camera tubes 10B, 10G, 10R, each image is passed to scanning corrector circuitry 37 generally indicated by the dashed line 37 in Figure 4. A common horizontal scan counter 14 and a common vertical scan counter 20 are provided in the same manner as the monochrome camera illustrated in Figure 2. However, connected to the horizontal scan counter and the vertical scan counter are red scan controller 25R, green scan controller 25G and blue scan controller 25B. Each of the red scan controller 25R, the green scan controller 25G, and the blue scan controller 25B corresponds to the components included within the area bounded by the dashed line 25 in Figure 2. Outputs from the red scan controller 25R, the green scan controller 25G and the blue scan controller 25B are connected to the red camera tube 10R, the green camera tube 10G and the blue camera tube 10B respectively. Data to be contained in the horizontal and vertical scan correctors in each of the scan controllers 25R, 25G and 25B is supplied by a corrector controller 36' which is responsive to the signals L' from the optical system 11' for its current arrangement. The outputs of the red camera tube 10R, the green camera tube 10G and the blue camera tube 10B are connected to a synchronisation formatter 12RGB for producing output video signals including synchronisation information. The synchronisation formatter 12RGB is responsive to the count output by the horizontal and vertical scan counters 14 and 20 to insert the appropriate synchronisation information in the output video signals.

There have been described two embodiments of a video image capture apparatus including means for compensating for the effects of optical imperfections. It will be appreciated that the particular embodiments described are illustrative and that many additions of
5 modifications are possible within the scope of the invention.

For example, in place of the horizontal and vertical scan tables 16 and 22 for converting the output of the horizontal and vertical scan counters 14 and 20, multiplier circuits could be used in an alternative embodiment of the invention. Also, rather than additive correction
10 values the horizontal and vertical correctors 15 and 21 could generate multiplicative correction factors, in which case the adders 17 and 23 would be replaced by multipliers. In fact, the elements called adders 17 and 23 could be any kind of combining component so long as this component can modify outputs of the scan tables 16 and 22 in a manner
15 corresponding to a required correction so that the deflection circuitry of the tube 10 is controlled to compensate for image distorting effects of the optical system.

Although, in the above described embodiment of the invention, only the correction function data for one lens stored in the mapping
20 memory storage 30 at any one time, it will be appreciated that the correction function data for a plurality of lenses could be stored (assuming a sufficiently large memory) with the control information C from the corrector controller 36 defining not only the current lens parameters (focus, zoom position etc.) but also the lens identity.

Also, as an alternative to down-loading the correction function data from an external source, the correction function data for a plurality of lenses could be held in a read only memory (associated with the corrector controller 36) and the data for one or more selected lenses down-loaded into the mapping memory during a non-active blanking
25 period.
30

Also, although an embodiment of the invention has been described with reference to a particular high definition television standard (namely that of the Society of Motion Picture and Television Engineers - SMPTE) it is equally applicable to other high definition television
35 systems, and also to lower definition systems, such as the conventional low definition systems with 625 or 525 lines per frame. In all cases the apparatus provides a higher quality video output from a video image

capture apparatus by mitigating the effects of optical imperfections.

The corrector controller 36 in the embodiments described above is responsive to signals L from the optical system 11 representing its current parameters to produce control information for the control input C of the scan correctors. In the case where the optical system 11 is used by more than one tube and tube target, the optical system 11 can include an optical beam splitter 13. The beam splitter 13 may also distort an image being passed through it and the corrector controller 36 could be made sensitive to control information from it. Further, the positioning of the individual tube targets within each tube 10, may be variable and may give rise to image distortion. In that case the corrector controller 36 could be made sensitive to control information from the or each tube 10 and tube target.

Also, although the specific embodiments describe scanning circuitry than scans the or each tube target along substantially horizontal scan lines, it should be understood that the invention could equally apply to other scanning arrangements. The horizontal and vertical address data used by the mapping storage 30 should therefore be understood to be address data capable of addressing any point within a scan pattern and is not limited to the specific embodiments described herein.

CLAIMS

1. A video image capture apparatus comprising at least a tube having a tube target for sensing light via an optical system, scanning
5 circuitry for causing scanning of the or each tube target and producing output signals according to the intensity of the light sensed by the or each tube target, digital deflection signal generating means for producing digital deflection signals for a scanning pattern for the or each tube target and, associated with the or each tube target, a scan
10 corrector for producing digital correction signals for modifying the scanning pattern for the respective tube target to compensate for the effects of imperfections of the optical system.

2. Apparatus according to Claim 1 in which the or each scan
15 corrector includes a horizontal scan corrector for producing a digital horizontal correction signal and a vertical scan corrector for producing a digital vertical correction signal.

3. Apparatus according to Claim 2 wherein the digital deflection
20 signal generating means produces a horizontal digital deflection signal and a vertical digital deflection signal,

the or each horizontal scan corrector is associated with a respective horizontal combining means and the or each vertical scan corrector is associated with a respective vertical combining means,

25 the or each horizontal combining means combines the digital horizontal deflection signal with the digital horizontal correction signal from the associated horizontal scan corrector to produce a digital horizontal scan signal and

the or each vertical combining means combines the digital
30 vertical deflection signal with the digital vertical correction signal from the associated vertical scan corrector to produce a digital vertical scan signal.

4. Apparatus according to Claim 3 including digital to analogue
35 converter means for converting the or each digital horizontal scan signal into a respective analogue horizontal scan signal and for converting the or each digital vertical scan signal into a respective

analogue vertical scan signal and

means to apply the analogue scan signals to respective scanning circuitry for causing scanning of the or each respective tube target.

- 5 5. Apparatus according to Claim 4 wherein the or each scanning pattern comprises a plurality of scan addresses, and the digital deflection signal generating means includes scanning counter means for sequentially incrementing a horizontal and a vertical scan address for the or each scanning pattern.

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6. Apparatus according to Claim 5 wherein the digital deflection signal generating means comprises a horizontal scan table store associated with the or each tube target, the or each horizontal scan table store containing horizontal deflection data and being responsive to the horizontal scan address from the scanning counter for producing the digital horizontal deflection signals and a vertical scan table store, associated with the or each tube target, the or each vertical scan table store containing vertical deflection data and being responsive to the vertical scan address from the scanning counter for producing the digital vertical deflection signals.

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7. Apparatus according to Claim 5 or Claim 6 in which the or each horizontal scan corrector comprises a horizontal mapping table addressed by the horizontal and vertical scan addresses from the scan counter and interpolator means for interpolating between data from the horizontal mapping table to produce the digital horizontal correction signal and the or each vertical scan corrector comprises a vertical mapping table addressed by the horizontal and vertical scan addresses from the scan counter and further interpolator means for interpolating between data from the vertical mapping table to produce the digital vertical correction signal.

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8. Apparatus according to Claim 7 wherein each mapping table is addressed by selected bits only from the horizontal and vertical scan counters.

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9. Apparatus according to any one of the preceding claims in which the optical system and/or the or each tube and tube target have varying parameters and the or each scan corrector is responsive to control signals representative of current parameters of the optical system and/or the or each tube and tube target to produce correction signals for compensating for the effects of imperfections of the optical system.
10. Apparatus according to Claim 9 comprising a corrector controller which is responsive to the varying parameters of the optical system and/or the or each tube and tube target to supply the control signals to the or each scan corrector.
11. Apparatus according to any one of the preceding claims including three tube targets, wherein each tube target is sensitive to a different primary colour.
12. Apparatus according to Claim 11 in which the optical system includes an optical beam splitter means and wherein each tube target is in a separate tube.
13. Apparatus substantially as hereinbefore described and illustrated with reference to the accompanying drawings.

Patents Act 1977

Examiner's report to the Comptroller under
Section 17 (The Search Report)

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Relevant Technical fields

(i) UK Cl (Edition K) H4T (TACC, TACK, TACP, TACR,
TATP)

(ii) Int Cl (Edition 5) H04N

Search Examiner

P J EASTERFIELD

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI, CLAIMS

Date of Search

19 SEPTEMBER 1991

Documents considered relevant following a search in respect of claims

1 TO 12

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2146879 A (FERRANTI)	
X	GB 2074416 A (AMPEX) whole document	1, 2, 3, 11
X	GB 1353147 A (EMI) whole document especially page 1 lines 19 to 29	1, 2, 3, 4, 5, 6, 7, 9, 11

Category	Identity of documents and relevant passages	Relevant to claim(s)

Categories of documents

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